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The Torque Referenced to a Perceived Exertion Level Is Affected by the Type of Movement in Men With Spinal Cord Injury

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Objectives: To compare a standardized submaximal intensity (based on the rate of perceived exertion [RPE]) with the percentage of the average and peak torque during a familiarization session in individuals with different spinal cord injury (SCI) levels in gravity-resisted and gravity-assisted movements. **Methods:** This was a cross-sectional study at a rehabilitation hospital. Thirty-six individuals stratified in tetraplegia (TP), high paraplegia (HP), and low paraplegia (LP) groups and 12 matched control participants (CG) were enrolled in the study. Participants performed a maximum strength test using isokinetic dynamometry. The familiarization consisted of 10 submaximal repetitions with a level 2 (i.e., 20% of the maximum score) in the Resistance Exercise Scale (OMNI-RES). Fisher's exact test compared the percentages of the average torque (%AT_{Fam}) and peak torque (%PT_{Fam}) of the familiarization (based on the peak torque during the maximum strength tests) to the %AT_{Fam} and %PT_{Fam} attained with 20% of RPE. The coefficient of variation (CV) was calculated to assess the torque dispersion during each familiarization set. **Results:** The %AT_{Fam} was lower for gravity-assisted compared to gravity-resisted movements for HP, LP, and CG ($p \le .05$). The CV was significantly lower in gravity-resisted movements during familiarization for TP, LP, and CG. **Conclusion:** Different RPE levels should be adopted for gravity-resisted or gravity-assisted upper limb exercises to maintain the same relative intensity during a familiarization session. **Key words:** *exercise test, muscle strength, perception, strength training, warm-up exercise*

Introduction

An accurate assessment of muscle strength is important to determine the workloads that should be used in training programs.[1] Many individuals who are evaluated using isokinetic dynamometry do not have any previous experience or knowledge of the strength assessment procedures.[2] Hence, a frequent finding of strength training studies is an increased peak torque during subsequent strength testing sessions, probably because subjects become more familiar with the procedures[3,4] and, consequently, are more likely to experience learning effects.[5]

Isokinetic devices are widely adopted to assess the strength of individuals with spinal cord injury (SCI) in clinical and research settings.[6-15] However, it is well recognized that individuals with SCI present trunk stabilization deficits, which impose restrictions during upper limb strength assessments.[14,16,17] Furthermore, proper body positioning might be influenced by the absence of strength in the lower limbs. Thus, a familiarization session is fundamental and provides a basis for a reliable and consistent assessment in this population.[2,18]

Currently, the familiarization adopted before the strength assessment in individuals with SCI is rather heterogeneous.[7-10,12,19-22] Although several studies reported using submaximal efforts, there is a lack of specification regarding the magnitude adopted as a reference for the submaximal intensity. The determination of a submaximal intensity is important to standardize the familiarization and to minimize the occurrence of muscle fatigue. For instance, Zoeller et al[6] adopted percentages (50%, 75%, and 100%) of the peak torque as a reference for the familiarization. However, this reference was arbitrary as the torque in maximum contractions was not predetermined.

On the other hand, the rate of perceived exertion (RPE) is defined as a subjective intensity of effort, strain, discomfort, and fatigue during aerobic or strength training.[23] Organizations such

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as the American College of Sports and Medicine and the American Heart Association recommend the monitoring of RPE during warm-up and familiarization to a maximum strength test.[2,18,24,25] Hence, the use of RPE scales could be a low cost and reliable alternative to standardize the magnitude of submaximal efforts during strength measurements in individuals with SCI.

Several studies have shown that during prolonged submaximal exercise, the RPE increases as a linear function of the percentage of total exercise duration.[26-28] In addition, RPE scales were considered an effective method to estimate the global effect of the training session[29] and to select training loads accurately.[30] However, some factors influence the intensity of RPE, such as sex,[31,32] the length of the muscle for a given load during both eccentric and concentric movements,[33] the velocity of the muscle contraction,[34] and muscle mass size.[35] The effects of gravity on the strength isokinetic test are fundamental to the measurement validity, as gravity-resisted or gravity-assisted movements might influence the results.[2] Gravity has been shown to affect significantly the peak torque of isokinetic testing.[36-38] During knee joint isokinetic testing, for example, the extension and flexion peak torque can be underestimated and overestimated, respectively.[36-38] Even though there is a large variability for gravity correction methods,[36-41] a standardized RPE might be influenced by movement direction or SCI level.

It should be emphasized that due to a lack of consensus of strength modifications after SCI compared to a control group of individuals without SCI, standardizations and reference values are fundamental to improve rehabilitation and to minimize the risk of injuries. Based on control group reference values, it is possible to associate the muscle strength of an individual with SCI to the degree of disability and rehabilitation purposes during different times of injury. The performance of most activities of daily life (ADLs), such as wheeling or transfers, are influenced by SCI level.[42-45] Thus, strength assessment patronizations and comparison with a control group of able-bodied individuals might provide valuable information regarding the necessity of protocol modification after SCI.

Therefore, the aim of the present study is to compare a standardized submaximal intensity (based upon the RPE) with the percentage of the average and peak torque during a familiarization session of upper limb strength tests in individuals with different SCI levels in gravity-resisted (elbow flexion and shoulder flexion and abduction) and gravity-assisted (elbow extension and shoulder extension and adduction) movements. We hypothesize that the average and peak torque of the familiarization, referenced as a percentage of the peak torque of a maximum strength test, will be higher than those from a perceived exertion level (20%) for gravity-resisted movements and will be similar for gravity-assisted movements for all SCI levels.

Methods

This study was approved by the Institutional Ethics Committee (protocol n. 53341616.0.0000.0022), and all participants provided written informed consent.

Participants

Thirty-six individuals with SCI were consecutively recruited from the rehabilitation program of a Network Center of Rehabilitation Hospitals (**Table 1**). Data were collected from December 2015 to May 2016.

Inclusion criteria were (a) male (over 18 years), (b) diagnosed with SCI, (c) complete motor lesion (ASIA Impairment Scale, AIS A or B),[16,17] (d) manual wheelchair user, and (e) no prior knowledge or never having performed a test in an isokinetic dynamometer. Participants were excluded if they had a history of metabolic disorders or cardiovascular, cardiac, or orthopedic surgery that would hamper an adequate exercise technique.

Physical activity level was estimated by hours of participation in sports and exercises, according to Janssen et al[46]: (1) sedentary (0 hours per week), (2) moderately active (1 to 3 hours per week), (3) active (3 to 6 hours per week), and (4) very active/athlete (more than 6 hours per week).

Participants were sequentially assigned to tetraplegia (TP; C6 to C8), high paraplegia (HP; T1 to T6), and low paraplegia (LP; T7 to L2) groups. The division between the first and second groups was in accordance with the ASIA tetraplegia classification and because of upper limb impairment.[16,17] The second and third groups differ in cardiovascular dysfunctions due to autonomic nervous system alterations and trunk instability. This division criterion has been previously used in SCI studies.[16,17,45,47-50]

In addition to the SCI groups, a control group (CG) composed of men without SCI, matched for age and body mass, was enrolled (**Table 1**). Participants of the CG were excluded if they presented metabolic disorders or cardiovascular, cardiorespiratory, or orthopedic limitations that might restrict test performance.

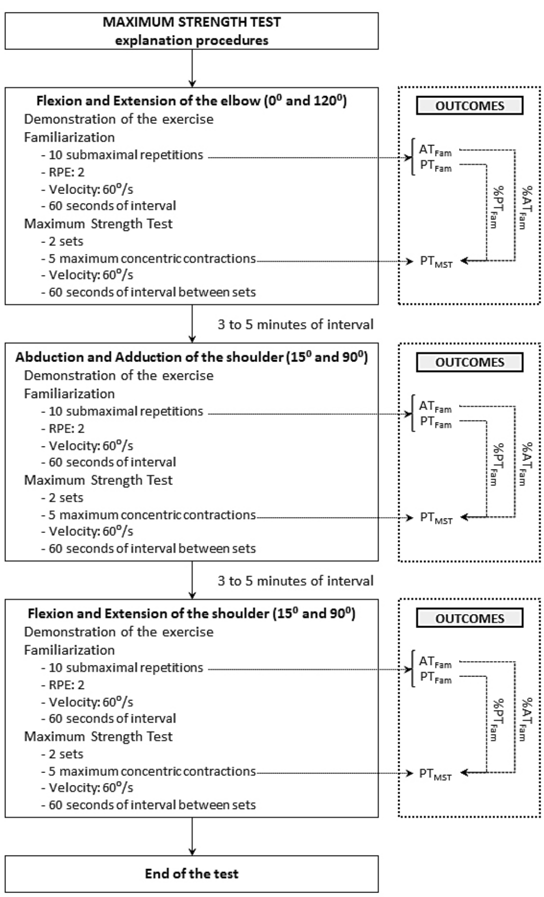

Figure 1. Flowchart of the study design and the main outcomes. AT_{Fam} = average torque of the familiarization (N.m); PT_{Fam} = peak torque of the familiarization (N.m); PT_{MST} = peak torque during the maximum strength test (N.m); RPE = rate of perceived exertion; $\%AT_{Fam}$ = percentage of the average torque of the familiarization based on the peak torque during the maximum strength test; $\%PT_{Fam}$ = percentage of the peak torque of the familiarization based on the peak torque during the maximum strength test.

Procedures

Each group performed the familiarization and the maximum strength test using the Biodex System 4 isokinetic dynamometer (Biodex Medical, Shirley, NY). The calibration followed the manufacturer's instructions.

The dynamometer rotational axis was aligned with the anatomical points of the elbow and shoulder joints. Reference points for flexion and extension of the elbow, abduction and adduction of the shoulder, and flexion and extension of the shoulder were lateral epicondyle, humeral head, and humeral tubercle, respectively. Force was exerted to the dynamometer through the hand by all participants. Tetraplegic individuals had the hand fixed with a neoprene strap.

The familiarization consisted of 10 submaximal repetitions at 60°/s (same velocity of the maximum strength test),[15] with a level 2 (easy; i.e., 20% of the maximum score) in the Resistance Exercise Scale (OMNI-RES) used for perceived exertion in strength exercise.[51] The familiarization included the same exercises and muscle actions of the maximal strength test (**Figure 1**).

The maximum strength tests were adapted from Kotajarvi and colleagues[8] and previous studies.[7,9] Despite the difficulty of trunk stabilization and the reduction or absence of upper and lower limb strength,[14,16,17] individuals with SCI have been tested in isokinetic devices.[6-14] Straps and belts were used on the trunk, pelvis, arm, and hands for better stabilization and positioning and to avoid compensatory movements.[52]

For individuals with tetraplegia, the limb with the most sacral myotome was chosen. For participants with HP or LP, only the dominant limb was assessed at 60°/s. Before testing, each exercise was demonstrated, and practice was performed to establish the range of motion (ROM) and to adjust the specific characteristics of each participant with the dynamometer. The nondominant limb grasped a handle to increase trunk stabilization. Five maximal voluntary concentric contractions were performed as follows: (1) flexion and extension of the elbow in the sagittal plane with a ROM of 0º to 120º (full elbow extension at 0º); (2) abduction and adduction of the shoulder in the frontal plane, with a ROM of 15º to 90º (shoulder abduction at 90º); and (3) flexion and extension of the shoulder in the sagittal plane, with a ROM of 15º to 90º (shoulder extension at 90º) (**Figure 1**).

The end ROM was measured with a goniometer; based on this value, ROM was calculated by the dynamometer. The weight of the upper limb and the dynamometer lever arm was standardized in relation to the starting position of each exercise. A rest interval of 5 minutes was provided between the shoulder and elbow testing.

Main outcomes

The percentages of the average torque ($\%AT_{Fam}$) and peak torque ($\%PT_{Fam}$) of the familiarization were based on the peak torque during the maximum strength tests (**Figure 1**). These parameters were statistically compared between gravity-assisted and gravity-resisted movements (SCI groups and CG) and calculated according to the following equations:

$$\%AT_{Fam} = \frac{AT_{Fam} \times 100}{PT_{MST}} \qquad \%PT_{Fam} = \frac{PT_{Fam} \times 100}{PT_{MST}}$$

where, AT_{Fam} is average torque of the familiarization (N.m), PT_{Fam} is peak torque of the familiarization (N.m), and PT_{MST} is peak torque during the maximum strength test (N.m).

Statistical analysis

The sample size was calculated based on a two-way analysis of variance (ANOVA), with moderate effect size (0.5), α-value of 5%, and 80% power (1 - β), demonstrating that a total of 48 individuals were required to compare four groups (TP, HP, LP, and CG).

The Shapiro–Wilk test was used to assess the normality assumptions. A two-way ANOVA with two between-group factors (gravity-assisted and gravity-resisted peak torques as main outcomes) and four within-group factors (TP, HP, LP, and CG) was performed for comparisons of the difference between $\%AT_{Fam}$ and $\%PT_{Fam}$. When the *F* test was significant, the Bonferroni test for multiple comparisons was used (height and peak torque). The Bartlett test of homogeneity of variances was used while the Kruskal Wallis test with Mann-Whitney post hoc was used for nonparametric variables (age, physical activity level, time since injury, body mass, and body mass index) to compare the groups. Cohen's *d* effect size (ES) was calculated to quantify peak torque differences between groups and was classified in the following manner[53]: trivial (*d* lower than 0.10), small (*d* between 0.10-0.29), moderate (*d* between 0.30-0.49), large (*d* between 0.50-0.69), very large (*d* between 0.70-0.89), and perfect (*d* of 0.90 or greater).

Fisher's exact test was performed to compare $\%AT_{Fam}$, $\%PT_{Fam}$, and coefficient of variation (CV) between groups and in each group separately. The CV was calculated for the familiarization and maximum strength test to assess the dispersion of the perceived exertion during each set.

The IBM SPSS statistical package (version 22.0; SPSS Inc, Armonk, NY) and G*Power statistical power software (version 3.1.9.2; Universität Kiel, Germany) were used. Statistical significance was set at 5% ($p \leq .05$; two-tailed).

Results

There were no dropouts in this study, and no significant differences were found in age, physical activity scale, body mass, and body mass index between groups. The time since injury was significantly lower in HP compared to TP. The CG presented significantly higher height compared to TP (**Table 1**).

The peak torque in the TP was significantly lower compared with the CG and LP except in shoulder abduction, in which no significant difference was found between TP and LP (47.3 vs 57.6 N.m, respectively; $p > .05$). However, the effect size comparing TP and LP for shoulder abduction peak torque was classified as perfect (ES = 0.95, Δ% = 17.9%). There were no significant differences in peak torque between HP, LP, and CG, considering all comparisons except for shoulder flexion, which was significantly lower in the HP versus CG. However, all peak torques of HP were lower than LP (ranging from -5.6% to 26.2%; ES ranged from 0.30 to 1.40). The peak torque of shoulder adduction and extension were significantly greater compared with shoulder abduction and flexion in the HP, LP, and CG (**Table 2**).

Table 1. Injury level characteristics by group

	TP (C6-C8)	HP (T1-T6)	LP (T7-L3)	CG
n	12	12	12	12
Age, years	31.5 (25.0–35.0)	25.5 (24.0–37.5)	40.5 (22.8–48.8)	38.5 (35.5–44.3)
Physical Activity Scale	2.5 (2.0–3.0)	3.0 (2.0–3.0)	3.0 (3.0–3.8)	3.0 (1.0–3.0)
TSI, months	81.7 (37.4–142.2)	20.8 (11.2–31.0)*	31.5 (20.3–92.7)	n.a.
Body mass, kg	64.5 (50.7–76.3)	68.3 (55.4–74.1)	69.2 (64.1–80.6)	78.4 (66.9–83.3)
Height, cm	165.8 (±5.7)	171.8 (±3.9)	169.3 (±5.2)	174.2 (±6.6)*
BMI, kg/m^2	22.5 (19.0–29.0)	22.3 (19.6–25.4)	24.1 (21.7–29.4)	26.2 (21.2–29.4)

Note: The variables are exhibited by median (percentiles 25 and 75). Height is shown by mean (±*SD*).
BMI = body mass index; CG = control group; HP = high paraplegia; LP = low paraplegia; n.a. = non-applicable; TP = tetraplegia; TSI = time since injury.
*Significant difference compared to TP ($p \leq .05$).

There were no significant differences between TP, HP, LP, and CG for $\%AT_{Fam}$ and $\%PT_{Fam}$ for all movements (**Tables 3** and **4**; **Figure 2**).

The $\%AT_{Fam}$ was significantly lower for elbow extension and shoulder adduction and extension compared to elbow flexion and shoulder abduction and flexion for the HP, LP, and CG ($p \leq .05$). The $\%AT_{Fam}$ at the elbow extension familiarization was not different from the elbow flexion in the TP ($p > .05$) (**Table 3** and **Figure 2**).

The $\%PT_{Fam}$ was significantly lower for the elbow extension compared to the elbow flexion on LP and CG ($p \leq .05$). The $\%PT_{Fam}$ was significantly higher for shoulder abduction compared to shoulder adduction on HP, LP, and CG ($p \leq .05$). Shoulder extension presented significantly lower $\%PT_{Fam}$ compared to shoulder flexion on all SCI groups (**Table 4** and **Figure 2**).

The coefficients of variation did not differ in the familiarization and strength test between groups. The gravity-assisted movements (elbow extension, shoulder adduction, and extension) had significantly higher coefficients of variations compared with elbow flexion, shoulder abduction, and flexion in the familiarization ($p \leq .05$). The coefficients of variation presented no differences in the maximum strength test (**Table 5**).

Discussion

The adoption of a perceived exertion-based submaximal intensity during a strength testing in individuals with SCI resulted in a different percentage of peak torque and average torque and was influenced by the type of movement. Our findings demonstrated that the responses might be independent of the SCI level and similar to nondisabled participants (CG). Although there was no significant difference in peak torque between groups, the percentual differences of peak torque achieved 45.1%, and the effect size ranged from 0.12 to 1.77.

Elbow extension and shoulder adduction and extension presented an average torque in the familiarization ranging from 14% to 33% of the peak torque of the maximum strength tests for all groups. These exercises are performed with gravity assistance, which probably facilitates movement control based on the perceived effort. However, the coefficients of variation in these movements were significantly higher compared to gravity-resisted movements. Even though the average torque percentage was close to 20% of the perceived exertion, the torque variability was higher in gravity-assisted movements. Brow and Weir[2] reported the influences of compensating effects due to the

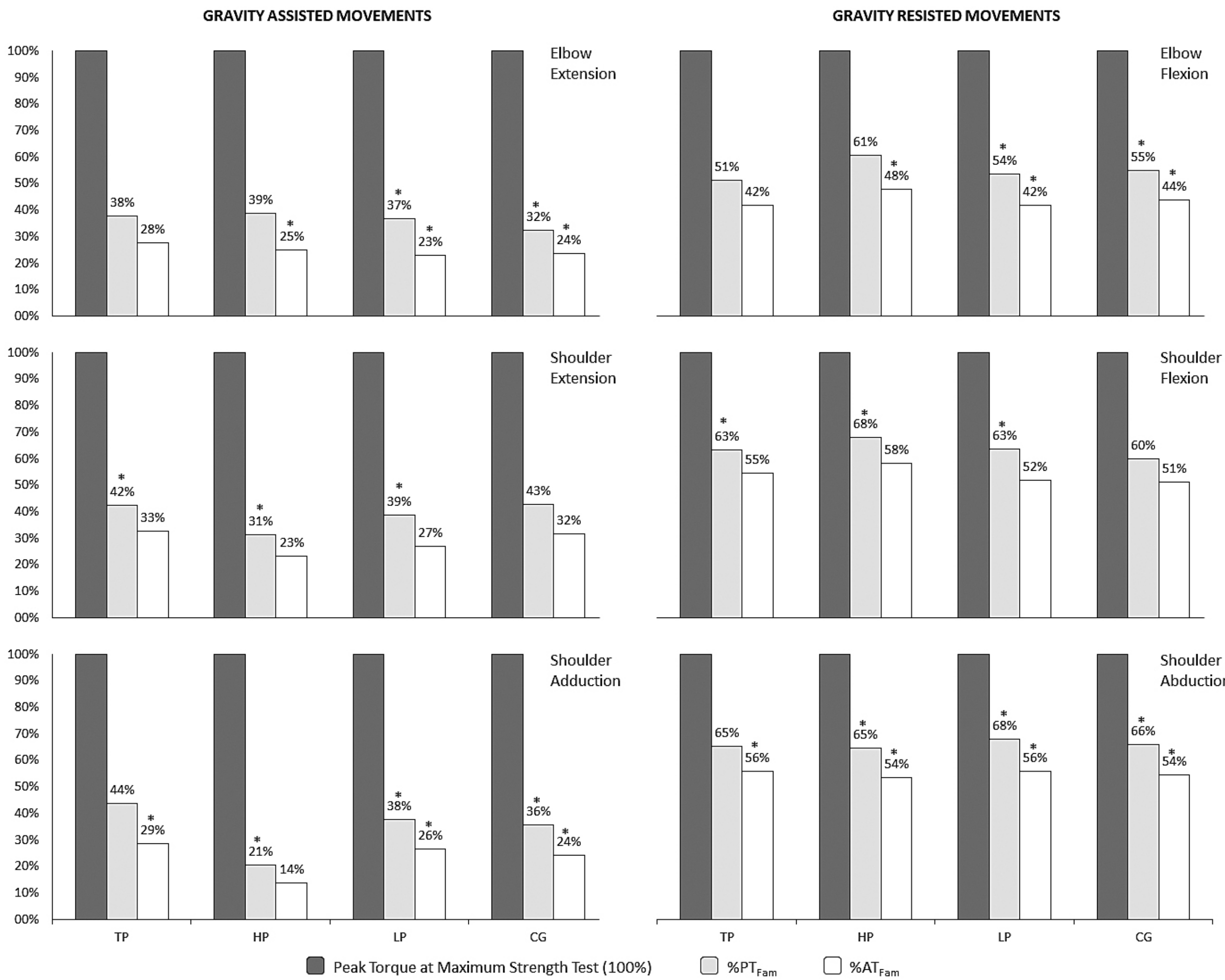

Figure 2. Group mean percentages of peak (%PT_{Fam}) and average (%AT_{Fam}) torques at familiarization based on the peak torque of maximum strength test for gravity-assisted and gravity-resisted movements. CG = control group; HP = high paraplegia (T1-T6); LP = low paraplegia (T7-L3); TP = tetraplegia (C6-C8). *Significant difference between gravity-assisted and gravity-resisted movement ($p \leq .05$).

gravity in a maximum isokinetic test. The isokinetic dynamometer weighs the lever arm and the assessed limb to correct gravity effect. Thus, a low level of perceived exertion for gravity-assisted movements is easily performed. However, to lift the limb's weight and the dynamometer lever arm against gravity can represent an effort higher than the level 2 of perceived exertion, mostly for individuals with higher levels of SCI. The average torque of the gravity-resisted contractions at familiarization ranged from 42% to 58% of the peak torque of the maximum strength test. This value was higher than the ones attained in gravity-assisted movements. Although the shoulder extension and adduction peak torque were significantly higher compared to shoulder flexion and abduction peak torque, only the paraplegia and control groups presented similar %AT_{Fam} between gravity-assisted and gravity-resisted movements for all groups. Consequently, neither the SCI level nor the magnitude of the peak torque interfered with the %AT_{Fam}.

The peak torque assessed at the familiarization ranged from 51% to 68% of the peak torque of the maximum strength test for gravity-resisted movements. These values were higher than the 20% perceived exertion reference, and the coefficient of variation was lower than those gravity-assisted movements. Therefore, the 10 repetitions executed against gravity at the familiarization were performed at a higher intensity compared to those performed with gravity assistance. However, it is possible to assume the occurrence of muscle fatigue during the maximum strength test, as the peak torque against gravity was lower compared to the gravity-assisted movements.

The shoulder adduction and extension's peak torque was also higher than shoulder abduction and flexion's peak torque in previous studies,[8,54-56] corroborating our findings. Regarding the elbow movements, three studies reported a higher peak torque at elbow flexion compared to elbow extension, contrary to our results.[8,55,56]

Torque variability is expected during submaximal concentric exercise. Previous studies adopted the one maximum repetition test to validate the OMNI-RES.[51,57] These tests are performed with a constant load, which is different from those adopted in the isokinetic maximum strength test. However, even on isoinertial tests, the perceived exertion varies during multiple repetitions.[57] Some studies recommended an isokinetic warm-up session with increasing intensity, ranging from 25% to 75% of the perceived exertion, with the purpose of not interfering with the maximum test results.[2,58,59] However, a relative intensity above 70% is classified as "vigorous" by the American College of Sports Medicine[60] and is normally used for hypertrophy and strength training.[61] Therefore, the present study contributes to the analysis of 20% of the perceived exertion in gravity-resisted and gravity-assisted movements.

In this study, the perceived exertion was set at level 2 (or 20% of the maximum effort). Prior to this study, we performed some pilot tests with a higher level of perceived exertion. Our priority was to maintain the same velocity of the maximum strength test during the familiarization process to benefit the learning process.[15] However, some individuals reached a higher peak torque in the familiarization process compared to the maximum

Table 2. Mean and *SD* of the peak torque (N.m) at the maximum strength test of the six concentric movements for injury level groups

	Elbow		Shoulder			
	Extension	**Flexion**	**Flexion**	**Extension**	**Abduction**	**Adduction**
Groups						
TP	34.3 (±19.5)	36.7 (±11.4)	51.9 (±14.3)	52.5 (±24.3)	47.3 (±10.9)	60.6 (±25.5)
HP	52.4 (±14.2)*	44.4 (±9.5)	56.5 (±14.3)	78.3 (±15.8)*‡	53.5 (±13.6)	85.8 (±16.1)*‡
LP	62.4 (±11.6)*‡	52.7 (±10.9)*	70.4 (±16.5)*	95.4 (±23.7)*‡	57.6 (±11.1)	99.1 (±22.7)*‡
CG	58.7 (±10.5)*	51.3 (±8.2)*	76.6 (±14.6)*†	92.6 (±19.2)*‡	66.0 (±10.4)*	90.9 (±12.5)*‡
Δ% (effect size)						
TP vs HP	-34.6% (0.93)	-17.4% (0.68)	-8.1% (0.32)	-33.0% (1.06)	-11.6% (0.57)	-29.3% (0.99)
TP vs LP	-45.1% (1.44)	-30.4% (1.40)	-26.2% (1.29)	-45.0% (1.77)	-17.9% (0.95)	-38.9% (1.51)
TP vs CG	-41.7% (1.25)	-28.5% (1.28)	-32.2% (1.72)	-43.3% (1.65)	-28.3% (1.72)	-33.3% (1.19)
HP vs LP	-16.1% (0.71)	-15.7% (0.87)	-19.8% (0.97)	-17.9% (1.08)	-7.1% (0.30)	-13.5% (0.83)
HP vs CG	-10.8% (0.45)	-13.4% (0.73)	-26.2% (1.40)	-15.5% (0.91)	-18.9% (0.92)	-5.6% (0.32)
LP vs CG	6.3% (0.32)	2.7% (0.13)	-8.0% (0.37)	3.0% (0.12)	-12.7% (0.75)	9.1% (0.36)

Note: CG = control group; HP = high paraplegia (T1-T6); LP = low paraplegia (T7-L3); TP = tetraplegia (C6-C8).
*Significant difference compared to TP ($p \leq .05$).
†Significant difference compared to HP ($p \leq .05$).
‡Significant difference compared to gravity resisted movement at the same joint and plane motion ($p \leq .05$).

Table 3. Group mean percentages of the average torques of the familiarization based on the peak torque of the maximum strength test (%AT_{Fam})

	TP	HP	LP	CG
Elbow				
Extension	27.6%	25.0%*	23.1%*	23.7%*
Flexion	41.8%	47.7%	41.8%	43.9%
Shoulder				
Flexion	54.5%	58.1%	51.9%	51.2%
Extension	32.7%*	23.3%*	27.0%*	31.5%*
Abduction	55.8%	53.6%	55.7%	54.3%
Adduction	28.7%*	13.8%*	26.4%*	24.0%*

Note: No significant difference between groups. CG = control group; HP = high paraplegia (T1-T6); LP = low paraplegia (T7-L3); TP = tetraplegia (C6-C8).
*Significant difference compared to gravity-resisted movement at the same joint and plane motion ($p \leq .05$).

Table 4. Group mean percentages of the peak torques at familiarization based on the peak torque of the maximum strength test (%PT_{Fam})

	TP	HP	LP	CG
Elbow				
Extension	37.6%	38.8%	36.6%*	32.4%*
Flexion	51.2%	60.7%	53.5%	55.0%
Shoulder				
Flexion	63.4%	68.1%	63.4%	59.8%
Extension	42.3%*	31.2%*	38.7%*	42.8%
Abduction	65.2%	64.5%	67.9%	65.8%
Adduction	43.6%	20.6%*	37.6%*	35.6%*

Note: No significant difference between groups. CG = control group; HP = high paraplegia (T1-T6); LP = low paraplegia (T7-L3); TP = tetraplegia (C6-C8).
*Significant difference compared to gravity-resisted movement at the same joint and plane motion ($p \leq .05$).

Table 5. Coefficients of variation of familiarization (FAM) and maximum strength test (MST) for spinal cord injuries groups (TP, HP, and LP) and control group

	TP		HP		LP		CG	
	FAM	MST	FAM	MST	FAM	MST	FAM	MST
Elbow								
Extension	38.3%*	16.5%	49.0%*	11.1%	44.7%*	10.7%	55.2%*	7.9%
Flexion	20.7%	11.4%	17.7%	6.8%	21.2%	6.5%	20.5%	5.6%
Shoulder								
Flexion	9.2%	9.8%	20.1%	5.8%	15.7%	6.2%	13.7%	5.5%
Extension	68.7%*	11.2%	40.4%	7.5%	45.4%*	7.3%	45.3%*	6.5%
Abduction	17.2%	6.9%	14.6%	6.8%	15.6%	6.6%	19.6%	7.9%
Adduction	62.5%*	12.0%	42.9%	10.6%	72.7%*	6.0%	59.4%*	7.9%

Note: No significant difference in FAM and MST between groups. CG = control group; HP = high paraplegia (T1-T6); LP = low paraplegia (T7-L3); TP = tetraplegia (C6-C8).
*Significant difference compared to gravity-resisted movement at the same joint and plane motion ($p \leq .05$).

strength test. Considering that the participants had never performed a maximum strength test in an isokinetic dynamometer, we decided to adopt a lower level of perceived exertion to minimize the risk of muscle fatigue during the test. In fact, with a level 2 of perceived exertion, the maximum peak torque at familiarization was 68% of the peak torque of maximum strength test. This result corroborates the proposal of using a lower level of effort perception to minimize the risk of torque peaks near to the maximum strength test.

A previous study has already validated the familiarization process using the perceived exertion for individuals with SCI.[15] However, the present research demonstrated that the perceived exertion must be adjusted depending on the movement.

Gravity-resisted movements might require lower perceived exertion in order to avoid the possibility of reduced peak torque during maximum strength testing. Moreover, the large torque variance during gravity-assisted movements might produce peripheral fatigue, and practitioners should have caution during the familiarization process to not interfere with the maximum test results.

Study Limitations

The individuals were stabilized with straps and belts, compensating the reduced trunk strength on higher SCI levels. The trunk musculature strength allows better support of the shoulder girdle[13]; this stabilization might lead to an overestimation of the peak torque for both the TP and HP groups. The possible peak torque overestimation and the large variance of groups peak torque means might have minimized the chances to detect significant differences between groups. An additional limitation is that the results of the current work cannot be generalized to other ratings of RPE. Future studies should elucidate if different efforts adopted during the familiarization could influence the results from a maximum test and if the relationship with peak torque changes depending on the exercise and velocity.

Conclusion

Our findings demonstrate that a standardized submaximal intensity based on a fixed perceived exertion of 20% corresponds approximately to the same percentage of the average torque gravity-assisted movements and might be independent of the SCI level. In addition, our findings demonstrate that the perceived exertion was influenced by the movement direction. We found that gravity-resisted movements overestimate the maximum and average relative familiarization torque expected for the same level of perceived exertion. From a practical standpoint, different perceived exertion levels should be adopted for gravity-assisted or gravity-resisted upper limb exercises to maintain the same relative intensity during a familiarization session. Adjusting the RPE properly during the familiarization might avoid fatigue and underestimate peak torque in gravity-resisted exercises.

Conflicts of Interest

The authors declare no conflicts of interest.

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